Chemical Reactions and Enzymes

The Case of the Missing Enzyme

Almost every chemical reaction that takes place in your body involves at least one enzyme. Enzymes act as catalysts by greatly increasing the rate at which chemical reactions occur. Without enzymes, chemical reactions would take place too slowly to support the activities of living organisms. The human body contains thousands of enzymes that participate in thousands of different chemical reactions. What would happen if a person was missing just one enzyme?

The answer to this question depends on which enzyme is missing. While you might not even notice the absence of some enzymes, you would be unable to survive without others. In many situations, the absence of an enzyme will produce a serious, but treatable, condition. Many of these diseases are hereditary, which means that they are passed from parents to their children. Some common hereditary diseases that result from the lack of an enzyme are albinism (absence of pigment in the skin and eyes), galactosemia (the inability to convert galactose to glucose), and phenylketonuria (the inability of the body to break down the amino acid phenylalanine). Of these three disorders, phenylketonuria is the most common.

About 1 in every 40,000 children born in the United States suffers from phenylketonuria, or PKU. Children with PKU lack phenylalanine hydroxylase, the enzyme responsible for converting phenylalanine into another amino acid called tyrosine. Because PKU sufferers lack this enzyme, phenylalanine is converted to a chemical called phenylpyruvate instead of tyrosine. The high levels of phenylpuruvate that accumulate in the bloodstream cause damage to the brain as well as other organs.

The brains of infants develop rapidly, so they are particularly susceptible to elevated levels of phenylpyruvate. If PKU goes undetected, infants with this disorder can suffer irreversible brain damage leading to severe mental retardation. Fortunately, this disorder can be easily detected and, if detected early, it can be controlled.

PKU was first discovered in 1934 by a Norwegian doctor, Dr. Asbjørn Følling. He made the discovery after a woman brought her two severely mentally retarded children to see him. She thought that there might be some explanation for their mental retardation, because her children were surrounded by a strange smell.

After repeated examination of the children's urine, Dr. Følling found that it contained phenylpyruvate. He hypothesized that the children's strange smell and retardation were caused by the phenylpyruvate.

To test his hypothesis, Dr. Følling examined 430 mental patients. Of the 430 patients, only ten had phynylpyruvate in their urine; however, there were three pairs of sibling in this group of ten. This led Dr. Følling to believe that the condition was inherited, or passed down from parents to children.

From Dr. Følling's research, you might think that only people suffering from PKU will have children with PKU or that the children of anyone suffering from PKU will automatically have PKU. Neither of these conclusions is correct.

When Dr. Følling conducted further tests on 22 families of PKU patients, he found that a majority of the siblings did not have PKU, nor did the parents. Dr. Følling's conclusion was that, in order to develop PKU, a child must inherit it from both parents, not just one. In addition, both parents must be "silent carriers" of the condition. This means that they both carry the condition, but never develop it. If both parents are carriers, their children have a 25 percent chance of developing PKU.

In many countries, all infants are tested for PKU at birth. If the results are positive, treatment begins immediately. Infants with PKU are not allowed to breastfeed because mother's milk contains phenylalanine. Instead, they are fed a special phenylalanine-free formula. After the age of three months, the infants are examined again. Some infants will have acquired the ability to tolerate phenylalanine and can start on a regular diet. Others must remain on a phenylalanine-free diet until they are able to tolerate phenylalanine. In some children, this may occur by age six. In others, it may not be until age twelve or even later.

Following a phenylalanine-free diet is quite challenging. Although most people have never even heard of it, phenylalanine is present in many foods. For example, phenylalanine is found in many proteins, so children on phenylalanine-free diets cannot eat high-protein foods such as eggs, meat, and beans. Other foods such as breakfast cereals, milks, fruits, and vegetables are allowed only in small portions. Even food that you might think would be acceptable may actually be a problem. For example, foods that are made with the artificial sweetener NutraSweet™ (aspartame) must be avoided because the sweetener contains phenylalanine. After reaching adulthood, people with PKU need only keep to a diet low in phenylalanine in order to remain healthy.

Critical Thinking

1. Why do you think an adult with PKU can tolerate small amounts of phenylalanine in their diet but a newborn infant cannot?

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2. People with PKU are unable to convert phenylalanine to tyrosine. The human body uses tyrosine to produce melanin, a dark pigment that colors skin and hair. How might PKU affect a person's appearance?

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3. Children on phenylalanine-free diets are not allowed to eat high-protein foods. What might be some foods that children with PKU could eat for breakfast, lunch, and dinner?

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